Dee Voltage Regulator for the 88-Inch Cyclotron*

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A new broadband Dee voltage regulator was designed and built for the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory. The previous regulator was obsolete, consequently, it was difficult to troubleshoot and repair. Additionally, during operation, it displayed problems of distortion and stability at certain frequencies. The new regulator uses off-the-shelf components that can detect and disable the RF during sparking events, protecting the RF driver system. Furthermore, it improves the tuning of the cyclotron and allows consistency in operation.

* Work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under Contract No. DE-AC02- 05CH11231.
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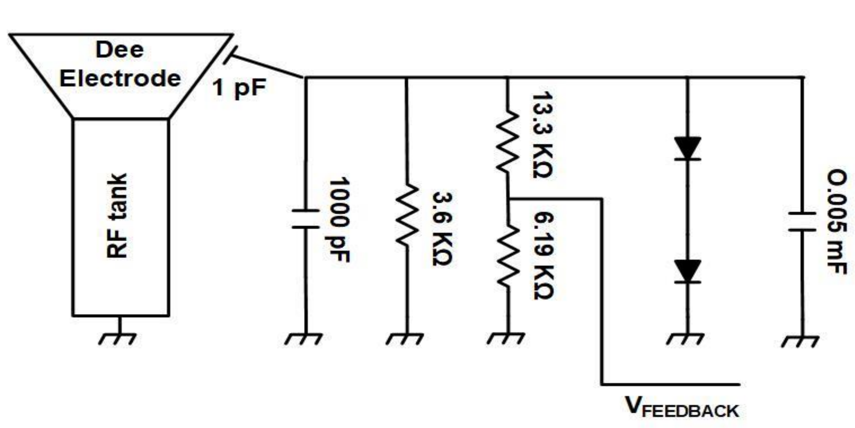
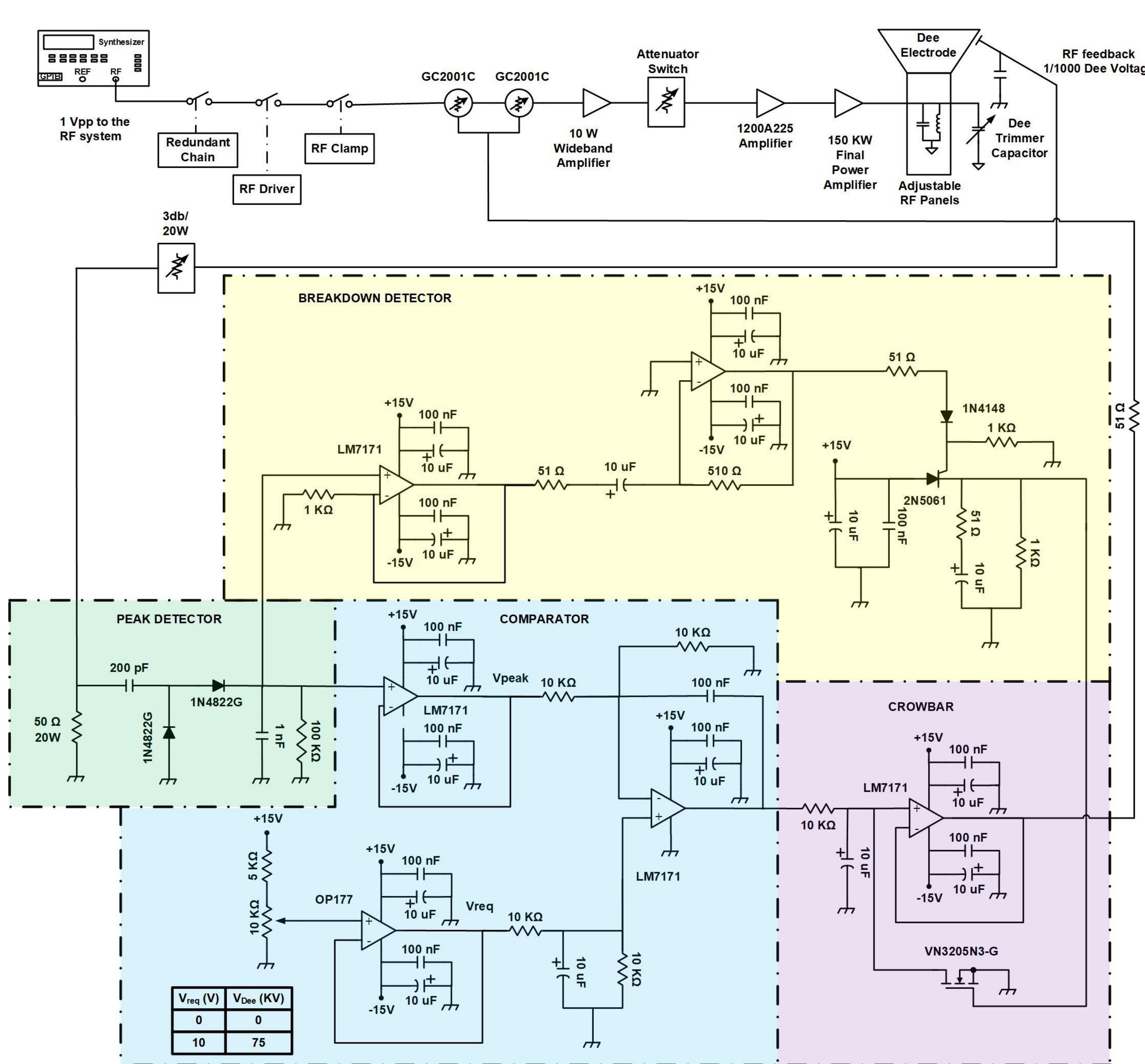
Dee Voltage Feedback

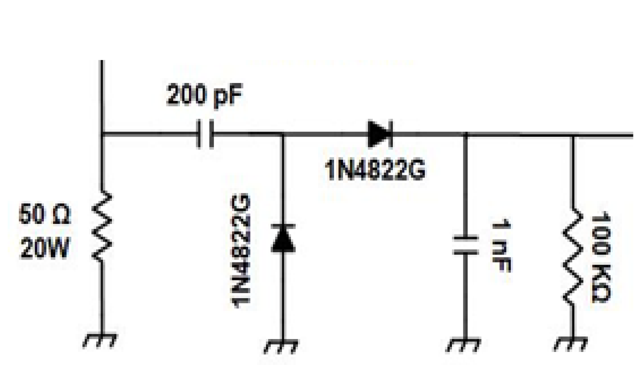


The probe consists of an isolated flush plate that faces the Dee electrode and has a 1 pF capacitance to the Dee electrode. A 1000 pF capacitor is connected to the plate to sample the RF, working as a 1/1000 divider. A resistor divider of 13.3 KΩ and 6.19 KΩ decreases the amplitude further, producing a feedback voltage, $V_{FEEDBACK}$, that is sent to the Dee voltage regulator.

Dee Voltage Regulator Interfaced with the RF System



Peak-to-peak Detector

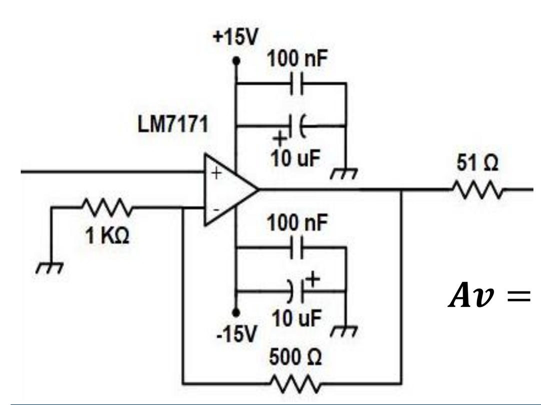


The peak-to-peak detector is a combination of two cascaded parts:

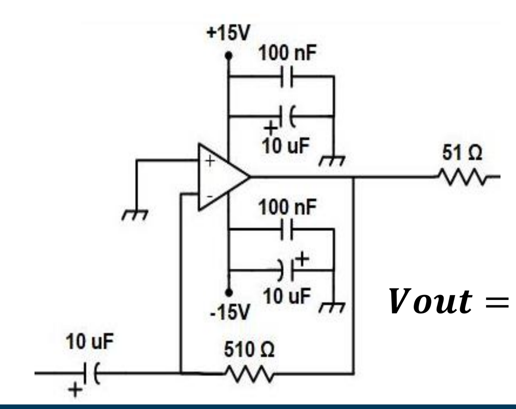
- The first is the clamp circuit formed by a capacitor and diode at the left. This translates the RF signal by its amplitude.
- The second is the peak rectifier circuit formed by a diode and capacitor at the right. It converts the RF signal of peak amplitude V_{peak} into a DC signal.

The capacitor of 1nF at the end of the circuit is charged up to the maximum voltage which corresponds to the peak-to-peak voltage, $2V_{peak}$.

Non-Inverting and Differentiator Amplifier

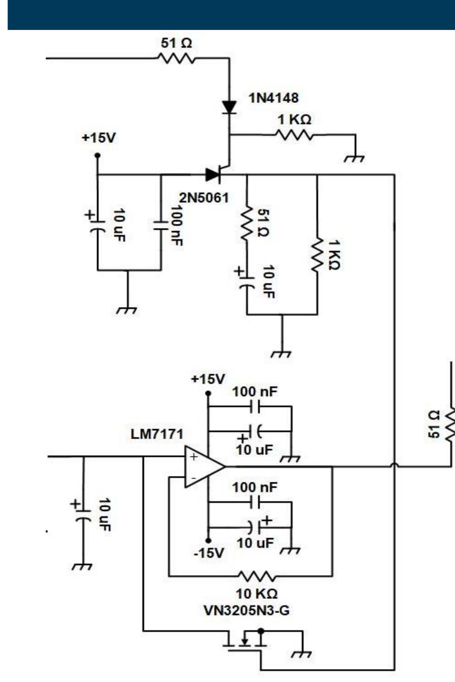


$$Av = 1 + \frac{R2}{R1} = 1 + \frac{500}{1000} = 1.5$$



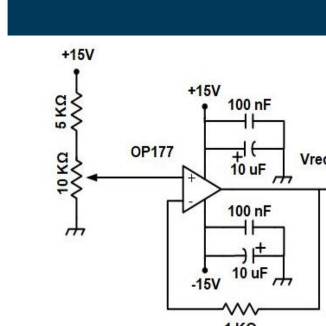
$$Vout = -RC\frac{d(Vin)}{dt}$$

Crowbar Circuit



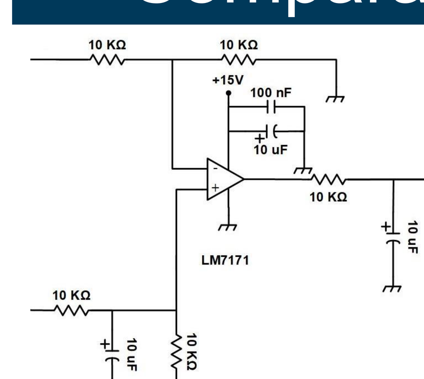
The 1N4148 allows only the positive cycle of the differentiator to cross and trigger the gate of the 2N5061 SCR.
After the SCR turns on, a forward current flows through the SCR and begins to charge the 10 μF capacitor through the 51 Ω resistor.
The SCR will remain on until the 10 μF capacitor is charged and the anode-to-cathode current drops below the holding current value.
The 1 KΩ resistor next to the 10 μF capacitor is a bleeder resistor that gives a time constant of 10 ms to the pulse applied to the gate of the VN3205N3-G metal-oxide-semiconductor field-effect transistor (MOSFET).
The MOSFET quickly discharge the 10 μF capacitor at the left bottom side of the figure.
Discharging the capacitor brings the voltage of the output of the LM7171 to zero applying maximum attenuation at the GC2001C voltage-controlled attenuator, consequently driving off the RF and protecting the RF system during a sparking event in the cyclotron.

Reference Voltage



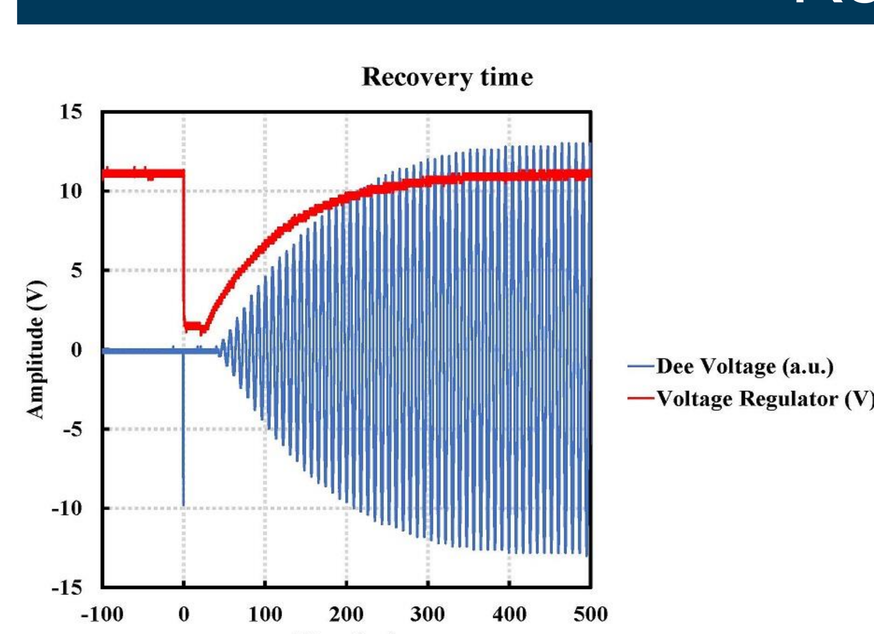
A 10 KΩ potentiometer gives the reference voltage that is buffered by the OP177 Ultraprecision Operational Amplifier and compared to the voltage from the peak-to-peak detector.

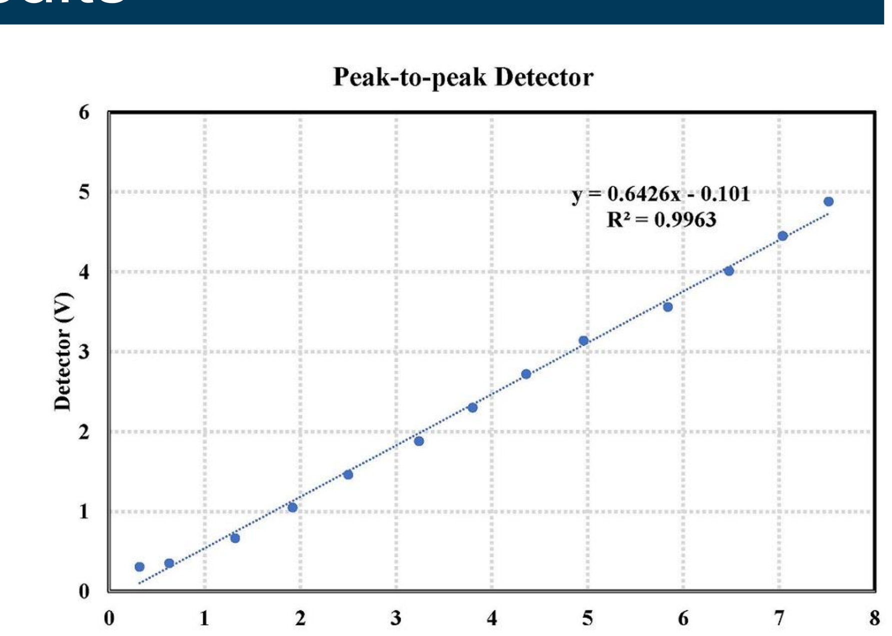
Comparator (Differential Amplifier Configuration)



The reference voltage is applied to the positive input of the LM7171 .
The peak-to-peak voltage is applied to the negative input of the LM7171 .
If the signal from the peak detector is above the requested voltage, the output voltage will decrease and the GC2001C attenuation will increase (or vice-versa), regulating the amplitude of the RF.

Results





Conclusions

The new regulator can detect and disable the RF during sparking events, allowing the plasma produced during these events to disappear and protecting the RF driver system. The new regulator will reduce the RF distortions and remove the stability issues allowing the cyclotron to be tuned more easily.

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88-Inch Cyclotron